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Innovative methodology for the prioritization of the Program of Measures for integrated water resources management of the Region of Crete, Greece

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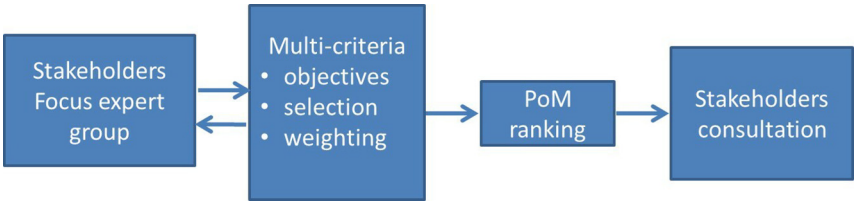
HIGHLIGHTS

- A multi-criteria evaluation process has been developed to prioritize the PoM.
- Stakeholder consultation was a critical component of the evaluation process.
- The methodology can be used to evaluate alternatives of a specific measure.

GRAPHICAL ABSTRACT



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ABSTRACT

An innovative multi-criteria methodology was proposed for the prioritization of the Program of Measures (PoM) in the Water Region of Crete, and applied specifically to the basin of Geropotamos river according to the requirements of the Water Framework Directive. This study relied on the four pillars of sustainability and the EU cross-compliance legislative objective for the minimization of the climate change impact. The multi-criteria evaluation methodology was based on the results of four different types of analyses: a DPSIR analysis, a SWOT analysis, a Cost-Benefit Analysis and a climate change impacts analysis. Public participation on the results of the study with local stakeholders was used at every stage of the multi-criteria evaluation process, from the selection and weighing of the criteria to the final ranking and measures' prioritization. The PoM contains two types of measures: basic measures which deal with the implementation of existing legislation and are the same for all regions of Greece and additional measures which are specified for the Region of Crete. The results of the prioritization process in Geropotamos Basin suggests that improving the water quality and ecological status of available water resources do not always require significant financial resources and can have a high impact in terms of achieving "good" quality status.

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1. Introduction

The Water Framework Directive 2000/60/EC (WFD) is the overarching regulatory instrument for the establishment of an integrated policy

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framework aiming to promote "good status" of all European waters by 2015 (Giakoumis and Voulvoulis, 2018). The Common Implementation Strategy (CIS) guidance documents (European Commission, 2012) provide a roadmap for the Member States (MS) with guidelines on how to reach the WFD objectives (Hattermann and Kundzewicz, 2009). The Blueprint to Safeguard Europe's Waters (COM, 2012) added a new dimension to the implementation by requiring MS to integrate socio-economic considerations in addition to having sufficient quantity and good quality water resources. As part of their WFD obligations, the MS had to produce River Basin Water Management Plans including a Program of Measures (PoM) that when implemented will improve the status of the water bodies that are classified as less than "good". The first Assessment of the WFD implementation was completed in 2015 (COM, 2015). There, the European Commission stressed that the most significant implementation problem faced by MS was the prioritization of measures. The selection of the best option from a series of alternatives constitutes a very demanding decision-making task that brings together multiple actors with often conflicting preferences, numerous solutions frequently with contradicting outcomes and various procedures often with inconsistent dynamics.

Against this background it becomes necessary to develop methodologies that facilitate the prioritization and the selection of measures. Multi-criteria evaluation techniques have been used in environmental management and policy-making in very different contexts to link primarily economic performance with environmental outcomes (Kiker et al., 2005). Recently however, there has been a big discussion on opening-up these previously strictly technocratic approaches to ensure active involvement of stakeholders and to take into consideration the complex socio-cultural and institutional context (Messner et al., 2006; Kallis et al., 2006; Munda, 2004; Huang et al., 2011). Furthermore, the integration of multi-criteria optimization with biophysical models and spatial analysis has shown great potential (Vollmer et al., 2016; Comino et al., 2016; Udias et al., 2016; Salgado et al., 2009) for managing water resources.

The need to broaden stakeholder involvement in shaping environmental policy is becoming increasingly acute as decision makers and regulators increasingly recognize the need to understand who is influenced by the policies they shape and who has the potential to influence them. The selection of the relevant stakeholders might prove to be particularly challenging with certain groups being marginalized or difficult to identify, other groups resisting participation due to pre-existing conflicts, and some groups being under-represented as a result of the need for more in-depth deliberation (Prell et al., 2009). Careful mapping of all stakeholders has become a necessity in order to ensure adequate representation of all interested parties. The benefits of such an analysis are multiple since they identify participants' interests, possible mechanisms of influence of other stakeholders, potential risks, key players and potentially inhibiting participants with negative attitudes (Reed et al., 2009).

The study presented in this paper adopted a case-study approach and aimed at the creation of an innovative framework for the prioritization of PoM in the Water Region of Crete, and specifically in Geropotamos basin, that is based on participatory-guided, multi-criteria and economic analyses and biophysical models. This work has been motivated by the need to improve water governance in Crete to facilitate the achievement of the WFD objectives and to adapt and mitigate forthcoming climate change challenges. Based on the assumption that participation and scale do matter for water policy outcomes, this study has attempted to provide a transparent decision making framework that minimizes uncertainties, communicates multi-disciplinary knowledge and allows ownership of the measures increasing in this way the chances for a more viable and efficient outcome.

More specifically, the study relied on the four pillars of sustainability (environment, economy, society and human well-being) and the EU cross-compliance legislative objective for the minimization of the climate change impact to create a multi-criteria evaluation methodology that is based on the results of four different types of analyses:

- The Drivers, Pressures, State, Impact Response (DPSIR) model of intervention, a key tool adopted by the European Environmental Agency to describe society – environment interactions
- The Strengths, Weaknesses, Opportunities, Threats (SWOT) Analysis, a decision making tool successfully applied in water resources management to identify the best solutions to interdisciplinary and mostly qualitative alternatives
- The Cost-Benefit Analysis (CBA), a valuable method of economic analysis that has been promoted through the CIS as the best tool to perform economic evaluation of the PoM
- The Climate Change Analysis, a modeling exercise conducted by Nikolaidis et al. (2016), using the Soil and Water Assessment Tool (Karst-SWAT version) –assessed the impact of climate change on the water resources for the Region of Crete.

These results are then used as input to the multi-criteria evaluation process to produce the output of prioritized measures. Public participation prepared on the basis of a thorough stakeholder analysis is ensured at every stage of the multi-criteria evaluation process from the selection and weighing of the criteria to the final ranking and measures' prioritization. The outcome is a PoM with prioritized, environmentally sound, and financially viable measures whose implementation enjoys the support and understanding of the local stakeholders thus standing better chances of success. This work is directly related to Sustainable Development Goal 6 which is clean water and sanitation, and Sustainable Development Goal 13 which is climate action.

2. Methodology for the prioritization of the program of measures

Geropotamos basin is located in central-southern part of Crete with an area of 525 km^2 and a population of about 35.000. The region has a typical Mediterranean climate characterized by high rainfall during the winter months and no rainfall during the summer months. The average annual precipitation in the area ranges from 300 mm to 600 mm and the average annual temperature is 17–20 °C.

The first implementation of the WFD for the Water Region of Crete was developed under the auspices of the Special Secretariat for Water (SSW - Ministry of Environment) and was approved in 2015. The Water Management Plan for Crete (SSW, 2015) included a complete PoM that was the result of public consultation where 55 stakeholder organizations out of the 355 invited, responded to the call for comments. The organizations that participated in the consultation included: Region of Crete, Decentralized Administration of Crete, 15 out of the 26 Municipalities of Crete, 8 out of 11 drinking water municipal companies, 5 out of 39 local irrigation organizations, universities and research centers, the Development Organization of Crete and NGOs. The consultation included meetings with the regional administration, public presentation and consultation at each Regional Unit, questionnaires on the consultation and consultation through the web. The input of the stakeholders in terms of suggested measures was taken under consideration in the final approved PoM.

The proposed methodology used for the prioritization of the PoM in the Water Region of Crete and specifically the measures applied to the Geropotamos river basin, is presented in Fig. 1. Based on literature review (Antunes et al., 2011; Hajkowicz and Collins, 2007; Munda, 2004; Munda, 2005; Salgado et al., 2009; Udias et al., 2016), and the basic concepts of integrated water management as developed by the

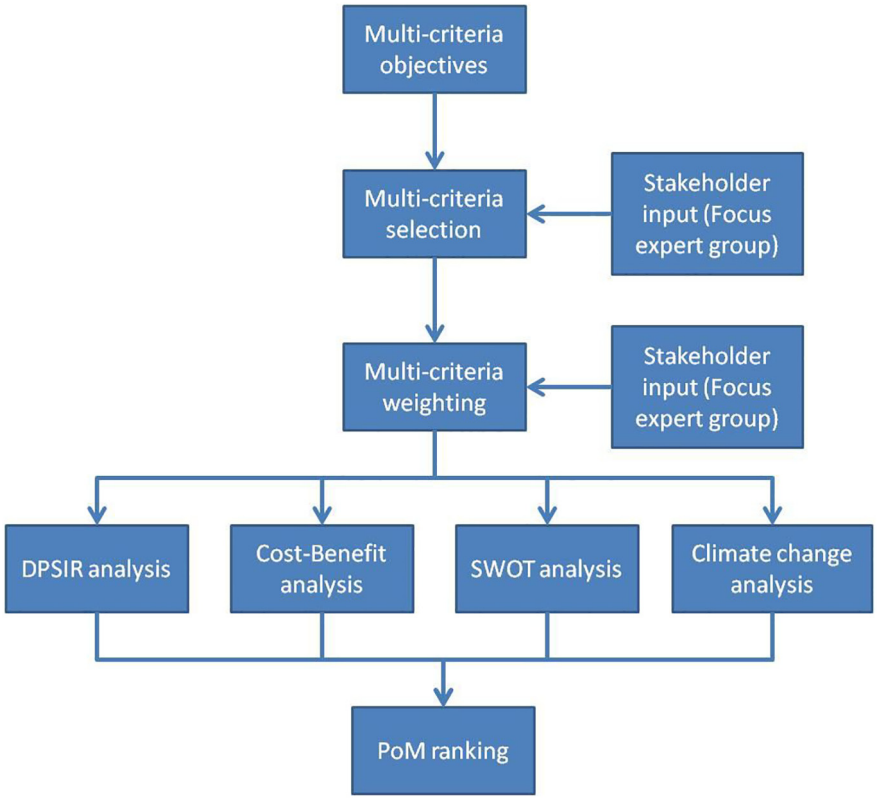

Fig. 1. Conceptual schematic of the methodology for the prioritization of the Program of Measures.

International Water Association (Grigg, 2010), it was decided to develop multiple criteria that would satisfy the following 5 objectives:

- Achievement of good status of all waters (good ecological and chemical status of surface water and good chemical and quantitative status of groundwater)
- Improvement of the growth potential and economic efficiency for the region
- Enhancement of social cohesion, well-being and life
- Improvement of degree of implementation of measure
- Mitigation of climate change impacts

The first four objectives relate to the four pillars of sustainability; environment, economy, society and human well-being. More specifically, the fourth objective supports the achievement of equitable societies, healthy ecosystems and socio-economic development in accordance with UN-Water Overarching goals (Zandaryaa, 2014) by facilitating the implementation of the selected measures. The fifth objective relates to an EU cross-compliance legislative objective which is to minimize the impacts of climate change. The next step was to identify several criteria for each objective that could be quantified as part of the multi-criteria analysis. Based on literature review (Ward, 2012; Salgado et al., 2009; Kiker et al., 2005), 3 to 4 individual criteria were selected for each objective for a total of 16 criteria that comprised the initial multi-criteria list. In order to evaluate both the objectives and the individual criteria, a questionnaire was created and was sent to an expert group. The questionnaire contained ranking of questions regarding the agreement of the stakeholders to the objectives of the multi-criteria analysis as well as the ranking and importance of the individual criteria in addition to allowing the stakeholder to explain free style the reasons of the agreements or the disagreement. The questionnaire was sent to a group of 33 stakeholders/experts that primarily deal with water management and environmental compliance. Fifteen responses were collected spanning most of the disciplines of the stakeholders (5/6 experts, 6/10 scientists, 4/12 personnel from water companies and municipalities, 0/4 representatives of region and government officials, and 0/1 NGOs). The questionnaire responses collected, were transferred to a suitable format to be analyzed. Comments from the expert focus group and analysis of the questionnaires resulted in a revised number of criteria that did not have overlaps and were clear and more succinct. The final number of criteria was 12.

The weight assigned to the objectives varied based on the input received from the expert group on their perception of importance of each objective. It was further broken down to the individual criteria based on feedback from the questionnaires and the expert community. Each criterion has a 5 point scale with 1 assigned to the lowest impact and 5 to the highest. Appendix I presents a complete list and description of the 5-point scale for each criterion. As a final step for the application of the multi-criteria analysis, the methodology requires that information is obtained from the following four studies before scoring for the prioritization of the PoM is carried out:

- DPSIR analysis for the water bodies of the Region of Crete - The DPSIR analysis of the River Basin Management Plan of Crete (GR13) had been carried out and submitted in 2015 by the Special Secretariat for Water (SSW) of the Ministry of Environment and the Water Department of the Decentralized Region of Crete (SSW, 2015). The Plan includes a comprehensive analysis of the driving forces exerting environmental pressures on water bodies, pressure and impact analysis and response to these impacts through the PoMs. This analysis is quantified and can be used to score the measures.

➢ SWOT analysis for each measure – It is a decision making tool that has been widely used in business management and has been successfully applied in identifying and solving problems related to water resources management, which often involve interdisciplinary, difficult to quantify issues (Mainali et al., 2011). This method was selected because it has the capacity to incorporate not only the present conditions (through strengths and weaknesses) but also the future conditions (through opportunities and threats) and this is very important for Greece which is undergoing rapid changes especially in terms of economic development and climate. In this study, SWOT analysis was used to evaluate each measure included in the PoM. SWOT analysis was conducted for each measure and the results were presented and discussed with users, water managers, planners and policy makers. Final SWOT analysis was revised according to their suggestions (Petousi et al., 2017).

➢ Cost-benefit analysis - CBA is a method of economic analysis that has been recommended in the WFD as a viable process to evaluate the PoM. The European Commission considers CBA and its relation to the WFD implementation in its first CIS guidance document as the tool to perform economic evaluation of alternative management and policy options. More specifically the CBA is used (Wateco, 2002):

- To determine the most cost effective measures that could be implemented to achieve good status of surface water and groundwater as stated in the WFD.
- To analyze the cost and the effectiveness of the Supplemental measures and weigh the cost benefit with relations to other measures that could be implemented.
- To identify the ways for the funding of the PoMs through various EU programs and
- To quantify the socio-economic benefits of each measure.

The cost for each measure was defined using the following:

- The Interim Progress Report by the SSW to the EU showing the Progress on the Implementation of PoM (http://cdr.eionet.europa.eu/gr/eu/wfdart153/).
- The program for the Agricultural Growth of Greece 2014–2020 (http://www.agrotikianaptixi.gr/).
- The Regional Business Plan of Crete 2014–2020 (funded by the Partnership Agreement for the Development Framework 2014–2020, www.espa.gr).
- The Business Plan for the Environment and Sustainable Development, Call for Bids 2014–2020 (http://www.epper.gr/el/Pages/PROSKLHSEIS_2014-2020.aspx).

The measures that have only administrative cost have been assigned a zero cost because they are executed by governmental personnel that their cost is already covered. This was a decision taken by the SSW and has been applied to financial studies undertaken by the Ministry. In our analysis, only additional costs are considered. The equivalent annual cost (€/year) for each measure taking into consideration the depreciation rate was estimated following the guidelines of the SSW:

- For the measures that resulted from a project funded by the Partnership Agreement for the Development Framework 2014–2020, the depreciation rate was equal to the duration of the program, i.e. 6 years.
- For water management measures the depreciation rate was 20 years.
- For major infrastructures such as dams, the depreciation rate was 50 years.
- For certain measures such as educational programs, the duration of the program indicated the depreciation period (3 years).

The benefit which can be expressed as the quantity of water that has either improved its' status or increased its' availability upon implementation of the specific measure (m^3/year) was calculated as follows:

- The potential quantity of water that is either improved or increased as a result of the implementation of a program.
- Data that resulted from the River Basin Management Plan or other detailed management plans.
- From the techno-economic study or technical description of similar projects implemented in Crete, that were funded by the NSRF (National Strategic Reference Framework) 2007–2013 or by the European Agricultural Fund for Rural Development 2007–2013.

The evaluation of each measure was based on the cost effectiveness of each measure. The WFD uses the expression $CE_i = \frac{C_i}{BE_i}$ where CE_i: is the ratio of cost to benefit of measure i, €/m^3, C_i: the cost of measure i, €, and BE_i: the benefit of measure i, m^3.

➢ Climate change analysis - The impacts of climate change to the water resources of Crete have been assessed using the SWAT-Karst model (Nikolaidis et al., 2016). Three IPCC climate change scenarios were evaluated regarding their impact to future hydrological conditions for the Region of Crete.

Finally, the PoM was divided into the following two groups and the ranking of each measure was performed following the above methodology:

- Basic Measures – Measures for the implementation of the European and national legislation and horizontal measures aimed at maintaining good status in all bodies of surface water and groundwater as laid out in the WFD. The basic measures are the same for all regions of Greece.
- Supplemental Measures – Additional measures aimed at fulfilling the goals of the WFD. The additional measures are specified for the Region of Crete.

The final stage was the public consultation where the results of the prioritization of the PoM were presented and the stakeholders' view on the methodology were recorded.

3. Results and discussion

3.1. Development of multi-criteria with stakeholder involvement

The results of the statistical analysis of the questionnaires showed an overall agreement with the adequacy of the 5 objectives and the criteria assessing the achievement of these objectives. In particular, 93% of the respondents fully agree with the adequacy of the 5 objectives for the prioritization of measures. Regarding the criteria for assessing the objectives, 93%, 86%, 86%, 79% and 72% of the respondents totally agree for the criteria established in each objective respectively. The questionnaire analysis as well as the direct consultation with stakeholders on how they understand the criteria, revealed overlaps and led to the consolidation of a few criteria resulting in the final list of 12 criteria presented in Table 1.

The weight assigned to the objectives varied based on the importance of each objective as it was perceived by the expert group. The experts ranked the first two objectives as having higher importance from the other 3. These objectives received the highest weight of 25% and 30% respectively. The first objective is the cornerstone of the WFD while the second objective which relates to the improvement of the growth potential of the region and economic efficiency is linked to the current

Table 1
List of objectives and corresponding criteria of the Multi-Criteria Analysis.

OBJECTIVE 1 – Achieving good status of all waters (good ecological and chemical status of surface water and good chemical and quantitative status of groundwater)
CRITERION 1.1: Impacts on ecological and chemical status of surface water and chemical and quantitative status of groundwater
CRITERION 1.2: Apparent impacts on the landscape (protected areas)
(This criterion includes all environmental issues related to the natural environment.)
CRITERION 1.3: Impacts on other ecosystems
(*This criterion includes all environmental issues, such as water and air quality, habitat loss, threatened species, aesthetics, noise,* etc.*)*
OBJECTIVE 2 – Improvement of area growth potential and economic efficiency
CRITERION 2.1: Financial Cost (implementation/operation)
CRITERION 2.2: Impact on economic activities
CRITERION 2.3: Conservation/increase of water resources (supply & demand)
OBJECTIVE 3 – Social cohesion, well-being and life quality
CRITERION 3.1: Impact on work - creation of new jobs
CRITERION 3.2: Safety and reliability of water distribution
OBJECTIVE 4 - Degree of implementation of actions
CRITERION 4.1: Required time for design and implementation
CRITERION 4.2: Technical and operational excellence, existence of necessary financial resources
CRITERION 4.3: Degree of social acceptance
OBJECTIVE 5 - Minimizing impacts of climate change
CRITERION 5.1: Impact of measure/project in minimizing the impacts of climate change (groundwater/surface water quality and quantity, reduction/increase in energy requirements, interventions in the natural environment)

economic situation of Greece. The last three objectives received 15%, 20% and 10% weight respectively with the last objective to have only one on/off criterion which relates to whether or not a measure minimizes the impacts of climate change. The weight of each objective was further broken down to the individual criteria based on the results from the questionnaires and the expert knowledge of the research group as follows:

- Objective 1 - Criterion 1.1 = 15%; Criterion 1.2 = 5%; Criterion 1.3 = 5%
- Objective 2 - Criterion 2.1 = 10%; Criterion 2.2 = 10%; Criterion 2.3 = 10%
- Objective 3 - Criterion 3.1 = 10%; Criterion 3.2 = 5%
- Objective 4 - Criterion 4.1 = 5%; Criterion 4.2 = 10%; Criterion 4.3 = 5%
- Objective 5 - Criterion 5.1 = 10%

The adequacy of the objectives and the individual criteria were further evaluated during the consultation period where the results from the ranking of the PoM were presented to the stakeholders of each sub-basin. At each consultation all the relevant stakeholders (water users, water providers, local NGOs, academic experts and regulators) were invited. The results of the prioritization of the PoM for their area were presented and then a structured dialogue was followed. The structured dialogue was chosen as a form of consultation because of the lack of cooperation from the stakeholders to fill out the questionnaires. The dialogue followed a pre-prescribed structure where the stakeholders were asked to comment on the following issues:

- identify the key issues in water management in their area
- propose measures they deem of high priority
- indicate their agreement with the objectives and criteria of the proposed prioritization methodology
- comment on the consultation approach and their acceptance of the project results.

The results of this part of the consultation will be illustrated for the case of Geropotamos sub-basin. In general, the two phase approach of involving the stakeholders both at the stage of the criteria elaboration and the stage of final results presentation was quite effective in terms of reaching consensus among the stakeholders.

The PoM contains two categories of measures: basic measures which are the same for all regions of Greece and additional measures which are specified for the Region of Crete. In total there are 65 basic measures and 45 additional measures. From that, 49 basic and 30 additional potentially could be applied in the Geropotamos Basin. Basic measures are compulsory for the PoM of each of the 14 water region of Greece. On the contrary, additional measures correspond to the specific water management needs and requirements in the Region of Crete. These include measures related to legislation, administration, economic development, water abstraction control, pollutant control, agriculture code of practice, demand management, reuse, aquifer recharge, wetland restoration, constructions, desalination project, research & development and education.

3.2. DPSIR analysis of Geropotamos Basin

The DPSIR analysis for the examined area is presented in Fig. 2. The main drivers that affect water resources in the area are agriculture, tourism and climate change. Specifically, the greatest part (>70%) of land is cultivated mainly for olive oil production and secondarily for vegetables production in greenhouses.

Beautiful beaches and famous antiquities attract thousands of tourists during the hot summer months highly increasing the drinking water demand (SSW, 2015). Climate change, following the more general Mediterranean trend of water resources shortages, has been projected as a serious threat for Geropotamos sub-basin by recent studies (Koutroulis et al., 2011).

These drivers create several pressures on the water resource system. For example, there are >40 olive mills in the area producing about 80.000 m^3 of olive mill wastewater annually. In addition, water collected at Faneromeni dam is used to irrigate 40,000 acres of agricultural land in Messara plain, including olive trees, horticulture etc. During the last decades, farmers have intensified the use of fertilizers and irrigation water seeking increased yields (SSW, 2015). Moreover, climate change is expected to increase evapotranspiration and water needs for plants in the future. In addition, domestic wastewater produced from the citizens and visitors are not well-treated in many cases (SSW, 2015).

The state of Geropotamos sub-basin under the pressures of the drivers is already not good. Specifically, the ecological status of surface

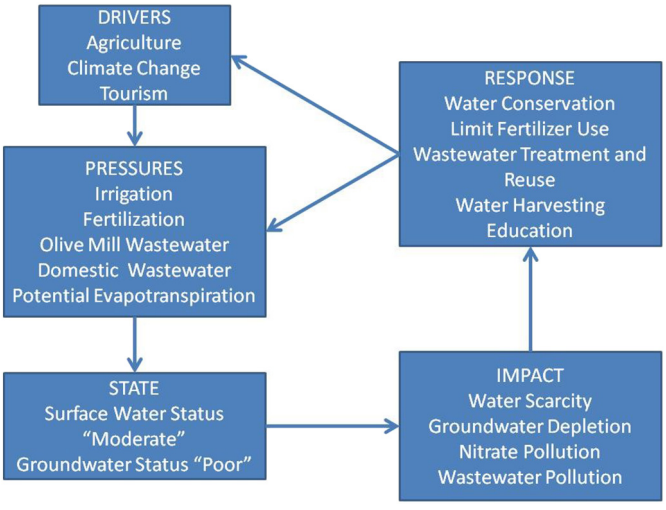

Fig. 2. DPSIR analysis in the study area.

Table 2
Summary of SWOT analysis regarding the implementation of measures contained in PoM.

Strengths	Weakness
-Faneromeni Dam operates in the area and 40,000 acres of agricultural land irrigated in Messara plain, including olive trees, horticulture and others. There are three Wastewater Treatment Plants (Timbaki, Matala and Moires), treating 5000 m^3/day -Messaras economy depends on agricultural production, tourism, sheep and goat farming. -Important archaeological sites such as Phaistos and Gortys. -Characterized Natura site, Special Protection Zone (GR4310012). -Protected areas intended for pumping water includes four water systems concerning the plain of Messara: GR1300091, GR1300092, GR1300093, GR1300302 -Olive groves and olive oil production in the area. -Significant development of early greenhouse crops (fruit and vegetables, floriculture) -Significant groundwater capacity. -There are two large bottled water companies in the area (Zaros and Rouvas). -There have been incentives from local authorities in Gergeri for proper water manager. -Rainwater collection has been a common practice since Minoan Crete and therefore has a widespread social acceptance. - The Agricultural School of Messara is located in the basin - A major agricultural exhibition take place every two year -The chemical and quantitative status of a significant part of the groundwater (GR1300071, GR1300330) has been defined as "good".	WWTPs final effluent ends to the soil. -The irrational use of irrigation water are threats to the availability of water. -Due to the large number of wells, groundwater is over-pumped. -Visible signs of surface contamination in the Vagionia area (domestic waste water, direct disposal of poultry, pesticide packaging). -The malfunctioning of the Messara slaughterhouse is impacting the good condition of the waters. -In the water system GRIVAL MOIRON GR 1300083 have been found signs of nitrate pollution. -The ecological status of a part of the surface water (GR39R001401041N & GR39R001401043N) has been defined as "moderate". - Chemical and quantitative status in a part of groundwater (GR1300072) has been identified as "poor". -There is lack of monitoring on disposal of olive mills wastewater. -Poor water management for irrigation. -The majority of water end users for irrigation have no awareness of water saving and water protection. -Difficulty on payment of water bills. -No irrigation water meters. -Strong seasonality in the annual rainfall volume can lead to complications of supply. -There are failures in the design of the dams - (over-dimensioning, wrong efficiency factor).
Opportunities	**Threats**
-Utilization of treated wastewater as an alternative source of irrigation water -Achieving good water status. -Water diversion from Platy river to the dam of Faneromeni -Optimal utilization of wastes after animals Slaughter. -Strengthening agro-tourism and «Natura» protected areas -Waste water reuse implementation. -Water-saving programs. -Economical exploitation of manure. -Improving irrigation efficiency. -Improvement of surface water and groundwater status. -Reuse of olive mills wastewater by-products. -Proposals for demarcation of a new vulnerable zone in the Messara area and the adoption of additional measures or reinforced actions. -Greenhouse roof rainwater collection, treatment and re-use of the greenhouses outputs -Training for proper water management. -Dissemination of drip irrigation application. -Water saving and management measures are important and could be implemented with low cost	-Absence of staff to manage and maintain processing irrigation networks. -The present economic and financial situation limits the funds available for public investments -Major drought periods during the summer months by processes associated with climate change -No Cost recovery of water-related services. -Lack of citizens' awareness -Lack of teamwork and cooperation -Limited data exchange between authorities involved in water quality monitoring

water is characterized as "moderate" and the chemical and quantitative status of groundwater are characterized as "poor" (SSW, 2015).

The impact on Geropotamos caused by the drivers and pressures includes: water scarcity, lowering of the groundwater level and sea water intrusion in the groundwater of the coastal area due to overexploitation, pollution of the groundwater due to increased use of fertilizers and finally, pollution of groundwater and surface waters by olive mill wastewater and domestic wastewater. To reduce the impact of the aforementioned pressures, a number of measures were adopted to improve the quantity and quality of the water resources: improvement of crop irrigation techniques, application of codes of good agricultural practice, appropriate treatment of domestic wastewater and olive mill wastewater, rainwater harvesting from greenhouse roofs, implementation of education and information campaigns.

3.3. SWOT analysis in Geropotamos

The SWOT matrix for the implementation of measures contained in PoMs for Geropotamos river basin is shown in Table 2. The SWOT analysis results can be summarized as follows:

- The Strengths of the area include a vibrant agricultural and tourism economy, adequate infrastructure and institutions to support the economic activities and significant portion of surface and ground waters are of "good" status.
- The Weaknesses of the area include ground water over-exploitation, seawater intrusion, nitrate pollution and water shortages.
- The Opportunities of the area include improvement of water body status, implementation of best water saving practices and strengthening agro-tourism.
- The Threats of the area include water shortages and droughts, lack of financing for the PoM and lack of cooperation.

3.4. Cost–benefit analysis

CBA was used to estimate the annual unit cost/benefit for each measure for the Geropotamos basin. A list of the annual cost/benefit values for the highest ranked basic and supplementary measures are presented in the Tables 3–4. The results from the CBA were used to rate Criteria 2.1, Criteria 3.1 and 3.2 of the Multi-Criteria Analysis. The top supplemental measures showed the importance of agriculture and the need to ensure the water availability and good status. The results for the Geropotamos Basin show the importance of ensuring water availability since the highest rated supplemental measure was the development of a Drought Contingency Plan since the effects of water scarcity on the availability of water supply for irrigation in the area is of great importance to the stakeholders. The Messara economy is primarily agriculture and tourism. This is seen in the measures that have the highest rating and can be grouped into the following categories: 1) climate change, 2) agriculture 3) drinking water, 4) water quality and finally 5) protection of the water resources and either maintaining or attaining good status.

3.5. Climate change impacts analysis

Nikolaidis et al. (2016) has conducted an analysis of the impacts of climate change for the region of Crete. The analysis included the determination of the present day average water budget for the region as well as the changes in the budget and the available water due to climate change (by simulating three climate change scenarios). This information was used to determine the current status of water availability as well as the projected water scarcity levels for the Geropotamos basin and then to provide the appropriate score to criterion 5.1 that examines if the measure is minimizing the impacts of climate change (groundwater/surface water quality and quantity, reduction/increase in energy requirements, interventions in the natural environment).

Table 3
Ranking and annual cost-benefit value of the top 15 basic measures for Geropotamos basin.

	Measure	Score	Annual cost-benefit (€/m^3*year)
1	Drawing up a strategic plan to address drought and water scarcity/GR13SM02-01 – Development of a strategic plan to address extreme drought and water scarcity for the Water District of Crete including mainly drought contingency planning based on a combination of various alternatives and measures to address the effects of water scarcity and drought.	4.10	0
2	Reduction of irrigation yields through improved irrigation techniques/GR13OM02-10 - Promotion of measures to improve irrigation techniques with water saving systems	4.10	0.003
3	Encouraging and enhancing the expansion of localized irrigation methods (Microarrays) to the potential of such irrigation plantations/GR13OM02-12. Expansion of the microarrays to all irrigated tree crops and increase of the percentage in susceptible to such systems other extensive farming (strawberry, asparagus etc.).	3.90	0.007
4	Modernization and rehabilitation/strengthening actions for the water supply networks of the major urban planning complexes of the Water District of Crete. Leak controls./GR13OM02-02	3.80	0.071
5	Protection zones definition for drinking water abstraction from groundwater/GR13OM03-01	3.80	0.007
6	Directive for the protection of groundwater (2006/118/EC)/GR13BM12 – Reformation of the groundwater monitoring network according to their final definition and their qualitative and quantitative status.	3.80	0.007
7	Drawing up and implementation of irrigation program within collective irrigation units/GR13OM02-09 - The measure involves the establishment of an irrigation program by the administrator of the network, in cooperation with the growers, in order to avoid the irrigation during the day of very high temperature.	3.80	0
8	Creation of a Unified Register of wastewater treatment areas, either through irrigation or artificial enrichment (Official Gazette Issue 354/B/08.03.2011)/GR13OM05-01	3.80	0.007
9	Prevention – Contamination Control (Directives 96/61/EC, 2008/1/EC, 2010/75/EU)/GR13BM06 - Completion of waste collection and treatment projects covered by the IPPC provisions.	3.80	0.2
10	Promotion of design and implementation of maintenance and rehabilitation projects for existing irrigation water transport pipelines/GR13OM02-03	3.75	0.003
11	Rationalization of the thresholds (minimum/maximum) of the necessary quantities of irrigation water according to the climatic conditions of Crete, the type of cultivation and the applied agricultural practices/GR13OM04-02	3.70	0
12	Reorganization/ Rationalization of the institutional framework for the operation of collective irrigation networks/ GR13OM02-08 - The measure refers to the formulation of proposals and institutional modifications related to the upgrading of the operation and the complete clarification of the institutional framework of the Local Organizations for Land Improvement (TOEB), in order to substantially improve the management of irrigation water.	3.70	0
13	Activities prohibited in protection zones of drinking water abstraction projects from aquifers/GR13OM03-02	3.65	0
14	Plant Protection Products (Directives 91/414/EEC - Regulation (EC) 1107/2009, 2009/128/EC)/GR13BM08 - Rational use of plant protection products	3.65	0
15	Specification and establishment of incentives for sustainable rainwater management/GR13OM02-05 - The measure includes the creation of a manual of specifications for rainwater collection and re-use, as well as the establishment of incentives for the construction of barrows for greenhouse cultivation, livestock farming and tourism facilities, especially in areas with increased water demand or high altitudes.	3.65	0.002

The present day average water budget for Crete was determined to be the following: average precipitation is 922 mm/yr or 7.6 billion m^3/yr, the evapotranspiration corresponds to 48.7% of the precipitation or 3.7 billion m^3/yr and the available water is 25.4% of the precipitation or 1.93 billion m^3/yr (Nikolaidis et al., 2016).

The availability of water in Crete is sufficient under average meteorological conditions because the present-day water demand is approximately 25% (485 million m^3/year) of the average available water, however, during the dry years, the available water drops to 780 million m^3/year which is less than double of the demand. Considering that 85% of the water demand is due to the increased need for irrigation in the summer months, then the severe water shortages being experienced in parts of Crete during drought years exert a significant pressure on water resources.

Geropotamos basin includes the main and largest agricultural basin of Crete and experiences significant water shortages that will be exacerbated in the coming years due to climate change. Nikolaidis et al. (2016) have estimated the Water Exploitation Index (WEI) for Geropotamos Basin. The present-day value of WEI for Geropotamos is in the range of 0.2–0.4 which suggests frequent water shortages and it is project to

Table 4
Ranking and annual cost-benefit value of the top 15 supplementary measures for Geropotamos basin.

	Measure	Score	Annual cost-benefit (€/m^3*year)
1	Measures for control/saving of water in areas with greenhouses GR13SM08-01	4.20	0
2	Application of Codes of Good Agricultural Practice aiming at water economy, water protection and reduction of nitrate pollution GR13SM06-01	4.20	0.002
3	Enforcement of necessary measures to address water scarcity or other emergencies GR13SM02-01	4.10	0
4	Enhancement of environmental program actions in Primary Education GR13SM15-03	4.00	0.003
5	Organization of information days on new technologies, modern cultivation techniques, environmental protection, fertility of agricultural soils etc. GR13SM15-01	3.95	0
6	Information and awareness of the public for issues about water GR13SM15-02	3.95	0
7	Agreements promotion with owners of tourist accommodation GR13SM16-03	3.90	0
8	Creation of protection rules for karst systems and sinks GR13SM05-02	3.85	0.001
9	Voluntary agreements to adopt initiatives and codes of conduct with large quantity water consumers GR13SM16-01	3.80	0.003
10	Artificial aquifer enrichment projects GR13SM09-01	3.80	0.248
11	Establishment and organization of standard farms GR13SM14-03	3.75	0.248
12	Conclusion of agreement between public and agricultural sector GR13SM16-02	3.70	0
13	Small-scale sewage treatment plants (<2000 population equivalent) in surface water systems assessed in 'incomplete' or 'moderate' status or 'poor quality' groundwater systems GR13SM11-07	3.70	0.248
14	Operation checks for the wastewater evaporators of the oil mills (2 times/year) GR13SM05-06	3.55	0.496
15	Short-range agro-environmental measures to reduce nitrate pollution - Protection of nitrate-sensitive areas GR14SM06-02	3.50	0.006

be between 0.4 and 0.6 and >0.6 depending on the scenario which suggests severe shortages throughout the basin. These are conditions that have been proved to lead to desertification. Relevant studies have indicated that Geropotamos River and Messara valley are prone to these conditions (Kritsotakis and Tsanis, 2009).

3.6. Prioritization of the PoM

Using the knowledge of the aforementioned studies, both basic and supplementary measures were ranked following the proposed methodology. Table 4 presents the top 15 ranked basic measures for the basin. There were 49 basic measures that applied to Geropotamos basin. Every measure was assigned a specific values/indicator for each criterion (see Appendix I) following the methodology presented earlier. The values/indicator ranged from 1 to 5. The total score was calculated as a weighted average of the product of value of indicator and the assigned weight (see Section 3.1) for all criteria. The highest score was 4.1/5 and the lowest 3.09/5. The average score was 3.53/5 (median = 3.55/5) and the standard deviation 0.24. Similarly, Table 4 presents the top 15 ranked supplementary measures. There were 27 supplementary measures that applied to Geropotamos basin. The highest score was 4.2/5 and the lowest 2.5/5. The average score was 3.51/5 (median = 3.55/5) and the standard deviation 0.47. Both distributions were normally distributed.

The ranking of the basic measures presented in Table 3 favored what were considered administrative measures that can be implemented with no additional cost. These are all legislative/regulatory measures that will reduce water losses and promote best management practices that will reduce water consumption in agriculture and improve the quality of surface and ground waters of the basin.

Similarly, the top 15 measures of the supplementary program deal mostly with regulatory and educational measures of best management practices and dissemination of such information. The 10 top measures out of the 15 deal are in that category. Measures that include small construction works for groundwater recharge, or wastewater treatment plants for small communities or environmental actions to reduce nitrate pollution were in the 10–15 rank.

The methodology promoted measures that had high impact with the lowest cost, water conservation, agricultural best management practices and legislative actions for the optimal management of available water resources (Basic measures in Table 3). A significant number of actions and measures can be taken with no to minimum cost that can have a significant impact to the environment and help in achieving the objectives of the WFD. Measures that involve construction works that have high cost to benefit ratio were placed lower in the priority list. A list of the annual cost/benefit values for the highest ranked basic and supplementary measures are presented in the Tables 3–4. The results of this prioritization exercise for Geropotamos basin clearly suggests that improving the water quality and status of available water resources does not always require significant financial resources.

The same methodology can be used in examining different alternatives of a specific project or measure and select the best option that has the highest impact.

The results of the study were presented to the local stakeholders of the Geropotamos Basin for public consultation to obtain their input. All the major stakeholder of the area were invited. They included representatives from the municipality, water company, irrigation works, farmers, and NGOs. Approximately 45 people attended the meeting and the mayor of the local municipality presided over the proceedings. These stakeholders represent >90% of the uses and users in the basin. The research team presented the methodology and the results of the prioritization of the PoM for their area and then a structured dialogue was followed. As mentioned earlier, the alternative of the structured dialogue was chosen as a form of stakeholder consultation due to the unwillingness of the participants to fill out the structured questionnaires. The Geropotamos area is mostly an agricultural area and most of the stakeholders are involved directly or indirectly in agricultural activities. Irrigation is conducted by the Local Farmers Irrigation Organizations that are minimally staffed by mostly secretarial personnel, governed by a farmer's council and do not employ agricultural specialist. These organizations actively fight for the rights of the farmers and participate in various consultations especially when the issue is water availability in the Region, however, they are not inclined to fill out questionnaires.

The discussion that followed identified the key issues of highest priority in water management that the local stakeholders had in their agenda. Their major concern was related to:

- safeguarding the availability of water supply for irrigation and implementing of construction works to increase the available water supply,
- improving the quality of drinking water due to nitrate contamination and finding alternative clean water supply,
- reversing sea water intrusion in the groundwater of the coastal area of the basin
- obtaining governmental financing to improve and expand the irrigation network in order to eliminate losses and improve efficiency.

Even though the results of this study established a very different priority in the PoM from the perception of the local stakeholders, the participants appreciated the methodology and the results of the study which identified in a rational way measures with low cost and high impact. Finally, the participants were in agreement with the proposed objectives and criteria of the prioritization methodology.

The experience of the consultation process used in this study suggests that the proposed methodology can be used for the prioritization of measures in a context of conflicting stakeholders interests and limited availability of alternative solutions due to financial restrictions.

4. Conclusions

An innovative multi-criteria methodology is presented that can be used for the WFD required prioritization of the PoM to improve the water quantity and quality in areas facing financial constraints and climate challenges. The methodology involves the identification of objectives, criteria and their weight with input from expert groups. The knowledge obtained from four background studies that include a DPSIR analysis, a SWOT analysis, a CBA and a Climate Change Impacts analysis was used for the scoring of the individual criteria and the ranking of all measures. Finally, local stakeholder input during the development of the multi-criteria analysis and the prioritization of measures help improve the ownership of the results suggesting a better implementation outcome.

The results presented for the Geropotamos Basin can be summarized as follows:

- The methodology gave high priority to “Measures to promote efficient and sustainable water use”. Eight of the first ten measures belong to this category. These include the development of a strategic plan to deal with drought and water scarcity and the adoption of various water-saving measures. These measures in most cases do not require significant costs and can have a high impact in terms of reducing water consumption.
- The ranking of complementary measures highlighted the specificities of the region. For the area of Geropotamos, it is important to save water from greenhouse crops. as well as to apply Good Agricultural Practices to save water and protect from nitrate pollution.
- Educational measures are relatively high priority.

All MS of EU are straggling to identify ways to set priorities in the PoMs and to comply with the WFD. The proposed methodology is a

viable alternative that can be used for setting priorities in the PoMs as well as for examining different alternatives for the same measure. It provides a transparent and well-informed participatory process where the stakeholders play a significant role in all the different phases of prioritization increasing the feeling of ownership and minimizing the potential for implementation derailment.

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Appendix I

OBJECTIVE 1 – Achieving good status of all waters (good ecological and chemical status of surface water and good chemical and quantitative status of groundwater)

CRITERION 1.1: Impacts on ecological and chemical status of surface water and chemical and quantitative status of groundwater

INDICATOR	DESCRIPTION
1	Significant impacts hardly mitigated, obligatory further review.
2	Significant impacts that are mitigated
3	Less than significant impacts that are easily mitigated.
4	There are no significant impacts.
5	There are no impacts.

CRITERION 1.2: Apparent impacts on the landscape (protected areas)

(This criterion includes all environmental issues related to the natural environment.)

INDICATOR	DESCRIPTION
1	Significant impacts hardly mitigated, obligatory further review.
2	Significant impacts that are mitigated
3	Less than significant impacts that are easily mitigated.
4	There are no significant impacts.
5	There are no impacts.

CRITERION 1.3: Impacts on other ecosystems

(*This criterion includes all environmental issues, such as water and air quality, habitat loss, threatened species, aesthetics, noise,* etc.*)*

INDICATOR	DESCRIPTION
1	Significant impacts hardly mitigated, obligatory further review.
2	Significant impacts that are mitigated
3	Less than significant impacts that are easily mitigated.
4	There are no significant impacts.
5	There are no impacts.

OBJECTIVE 2 – Improvement of area growth potential and economic efficiency

CRITERION 2.1: Financial Cost (implementation/operation)

INDICATOR	DESCRIPTION
1	The measures ranked in the last 20% of the total.
2	The measures ranked in the fourth 20% of the total.
3	The measures ranked in the third 20% of the total.
4	The measures ranked in the second 20% of the total.
5	The measures ranked in the first 20% of the total.

CRITERION 2.2: Impact on economic activities and innovation

INDICATOR	DESCRIPTION
1	Significant negative impact on economic activities (reduction of economic activity in the primary, secondary and tertiary sectors)
2	Negative impact on economic activities (reduction of economic activity in the primary, secondary and tertiary sectors)
3	Neutral impact on economic activities.
4	Positive impact on economic activities (improvement of economic activity in primary, secondary and tertiary sectors)
5	Innovation – significant positive impact on economic activity (increase of economic activity in the primary, secondary and tertiary sectors).

CRITERION 2.3: Conservation/increase of water resources (supply & demand)

INDICATOR	DESCRIPTION
1	Extremely high demand and very short supply with serious supply problems. It negatively affects both demand and supply.
2	Very high demand and short-term supply with a moderate supply problem. It negatively affects both demand and supply, but it is short-term.
3	Balanced demand and supply. It does not affect either demand or supply.
4	Moderate demand and medium-term provision. It improves supply and does not affect demand.
5	No problem with supply and demand. It affects positively

OBJECTIVE 3 – Social cohesion, well-being and life quality

CRITERION 3.1: Impact on work - creation of new jobs

INDICATOR	DESCRIPTION
1	The measure will result in job losses.
2	The measure will not create new jobs/will not result in job losses.
3	The measure may create new jobs in the future.
4	The measure will directly create new jobs - temporary
5	The measure will directly create new jobs - permanent.

CRITERION 3.2: Safety and reliability of water distribution

INDICATOR	DESCRIPTION
1	Non reliable and safe water distribution, unequal distribution in a wide range.
2	Non reliable distribution, disorders and adverse effects during emergencies
3	Neutrality in the safety and reliability of water distribution.
4	Reliable and safe distribution even in emergency situations.
5	Development and safe distribution even in emergency situations.

OBJECTIVE 4 - Degree of implementation of actions

CRITERION 4.1: Required time for design and implementation

INDICATOR	DESCRIPTION
1	None of the required studies/permits have been issued, the right to use water has not been clarified. There is no appropriate institutional framework governing the implementation of the project. There is no insurance of the site of installation and the transport/distribution of water by the project implementation body
2	A lot of the required studies/permits have not been issued, the right to use water has not been clarified, but there is a possibility of solving it. There is a consultation on the creation of the institutional framework governing the implementation of the project. There is a limited possibility of ensuring the site of installation of the project and the transport/distribution of water and has not yet been secured by the project implementation body.
3	About half of the required studies/permits have been issued, there are some issues concerning the right to use water. There is a draft legislative act governing the implementation of the project. There is an important and viable option of ensuring the site of installation of the project and the water transport/distribution, but they have not yet been secured by the project implementation body.
4	Most of the required studies/permits have been issued, most water-related issues have been solved. There is an institutional framework partly covering the implementation of the project. The site and water transport/distribution options are available, belong to or are very close to be obtained by the project implementation body.
5	All the required studies/permits have been issued, including water-use permits. There is an institutional framework that fully covers the implementation of the project. All the required agreements have been signed, the project implementation body has ensured the required site of installation for the project and the transport/distribution of water.

CRITERION 4.2: Technical and operational excellence, existence of necessary financial resources

INDICATOR	DESCRIPTION
1	Very little technical and functional excellence, availability of financial resources
2	Little technical and functional excellence, availability of financial resources
3	Moderate technical and functional excellence, availability of financial resources
4	Significant technical and functional excellence, availability of financial resources
5	Extremely significant technical and functional excellence, availability of financial resources

CRITERION 4.3: Degree of social acceptance

INDICATOR	DESCRIPTION
1	Strong opposition for the project from the political actors and society. The project is considered to bring about a great change in the way of life.

(continued on next page)

(*continued*)

OBJECTIVE 4 - Degree of implementation of actions	
2	The view of political actors and society is not clear, or the project has not been notified in order to create an opinion.
3	Society is up to date and opinions are shared in positive and negative at a percentage of 50/50. The project may involve changes in the way of life of residents and/or the social training is necessary for the implementation of the action.
4	Most of the political actors and society support the actions. The project does not bring about changes in the way of life of the residents. Public actors would like to participate in the project.
5	The project is supported by the political actors and the society. The project meets major/urgent health and safety requirements.
OBJECTIVE 5 - Minimizing impacts of climate change	
CRITERION 5.1: Impact of measure/project in minimizing the impacts of climate change (groundwater/surface water quality and quantity, reduction/increase in energy requirements, interventions in the natural environment)	
INDICATOR	**DESCRIPTION**
1	Very negative impact - Decrease of adequacy and deterioration of water quality with increasing energy requirements and generally negative interventions in the natural environment.
2	Negative impact- Decrease of adequacy and/or deterioration of water resources quality with/without increasing energy requirements and generally negative interventions in the natural environment.
3	Neutral impact- Conservation of adequacy, non-deterioration of water quality without increasing energy requirements and without negative interventions in the natural environment.
4	Positive impact - Improvement of water resources adequacy and/or improvement with/without reduction of energy requirements and generally positive interventions in the natural environment.
5	Very positive impact – Improvement of water resources adequacy and quality by reducing energy requirements and generally positive interventions in the natural environment.

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